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# Silica Dust Exposure and Efficacy of Dust Control System in Small Silica Flour Mills, India


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**ABSTRACT**

*Exposure to crystalline silica (quartz) gives a lung disease called Silicosis. Silico-tuberculosis is also commonly found in silica exposed workers. Exposure to silica dust in India has been extensively studied in agate, slate pencil, ceramic industries. However, exposure to silica dust has not been reported in silica flour mills in India. In the present investigation, silica dust exposure is reported in six silica flour mills of Beawar,Rajasthan, India. Total and respirable dust samples were collected from feeding and bagging operations of silica flour mills in Rajasthan, India. All the samples were found to have crystalline silica concentrations above the permissible exposure levels. A dust control system was designed and installed at one of the mills and efficacy of the system was tested with respect to total and respirable dust.*

**KEYWORDS: Silica flour milling, Crystalline silica, Quartz, Silicosis, Dust control system**

## INTRODUCTION

Silicosis is the most ancient and common of all occupational diseases. Even today, it continues to be among the most serious occupational diseases. Crystalline silica (quartz), the agent responsible for the causation of silicosis and silico-tuberculosis, is one of the most powerful fibrogenic matter found in nature. It has been classified as a carcinogen to humans (Group I) also by IARC (1997).With its potential to cause progressive physical disability, silicosis continues to be one of the most important occupational health illnesses in the world. Despite all efforts to prevent it, silicosis still persists worldwide. This incurable disease affects tens of millions of workers engaged in hazardous dusty occupations in many countries (Fedotov and Eijkemans 2007).

Free silica (SiO2) occurs in different polymorphic forms like quartz, cristoballite and tridymite. Crystoballite and Tridymite are products of high temperatures and may be observed in volcanic ash (Davis et al 1984) and are rarely found in industrial samples (NIOSH 1994). Silicosis occurs in occupations like hammer type silica milling (Bhagia et al 2007), agate industry (Bhagia et al 2004; Bhagia et al 2007; Sadhu et al 1995; Jiang et al 2002), slate pencil industry (Saiyed et al1985; Saiyed and Chatterjee 1985; Jain et al1977) ceramic and pottery (Saiyed et al 1995), Gold mining (Hnizdo and Sluis-Cremer 1993).Silicosis and silico-tuberculosis can also occur in foundries, glass, mining of stones containing free silica, etc. Ambient silica dust exposure in the vicinity of agate and slate-pencil industry has also been reported (Bhagia et al 2007; Bhagia 2009).

Silica flour is used industrially as an abrasive cleaner and as inert filler. Silica flour is used in paints, glass, ceramics, porcelain, toothpaste, scouring powder, Skin care products, clay production, as an additive in soaps, tiles and metal polish, a component in road surfacing mixtures. It is also used in some foundry processes (NIOSH 1981). The general population is exposed dermally to silica flour through its use as an abrasive additive in soaps, skin care products, and paints, and orally exposed through its use in toothpastes and as filler in numerous pharmaceuticals. Crystalline silica is also used in foundry work and in glass, ceramic, porcelain, tile, and clay production.

There is no cure for silicosis but the disease is preventable. For the prevention, exposure of workers to crystalline silica needs to be reduced. Where the reduction of silica dust exposure has been successful, the incidence rate of silicosis has decreased. This trend can be seen in many industrialized countries. Some countries have made significant progress towards the elimination of this disease. An effective silicosis preventive strategy should be based on the primary and secondary prevention approaches. The former includes the control of silica hazard at source by the engineering methods of dust control. The latter includes the surveillance of the working environment to assess the adequacy of dust control measures, exposure evaluation to assess the health risk for workers, and surveillance of the workers' health for early detection of the disease. In countries like the US and in Europe where appropriate measures have been taken, the incidence of silicosis has decreased dramatically. It is clear that to eliminate silicosis, the main focus has to be on prevention (Fedotov and Eijkemans 2007).

Engineering control is the most powerful tool for the reducing dust exposure at source. This study was conducted with the objectives to monitor dust levels in silica flour mills (commonly called ball mills at Beawar), design a dust control system and test the efficacy of dust control system. Silica flour is a finely ground crystalline silica (quartz). Occupational exposure in silica flour mills of Beawar (Rajasthan, India) has not been reported so far. The dust control system was designed and installed at one of the silica flour mills. Efficacy of the system was tested by carrying out dust monitoring before and after the installation of dust control system.

## METHODS AND MATERIALS:

### Selection of mills

There are two types of silica mills in India viz. hammer type (product mesh size <100) and ball mill type (product mesh size 100-500). US mesh size conversion to microns is given in Table-1. There are about 200 small silica flour mills at Beawar (Rajasthan, India). Dust monitoring was carried out in six small silica flour mills and the results were compared with national and international permissible exposure levels for quartz.

**Table-1 Mesh size micron conversion chart***

| US mesh | Microns |
|---|---|
| 50 | 300 |
| 100 | 149 |
| 200 | 74 |
| 325 | 44 |
| 400 | 37 |
| 500 | 30 |

*(www.showmegold.org/news/Mesh.html)

### Manufacturing process

Raw materials are brought from the mines. The first process includes feeding of raw materials to ball mill (Fig.1). The ball mill is then rotated with the powerful motor of 100hp. The ball mill contains balls which

while rotating crush the stones. Airborne material goes to the separator at the top by a powerful air draught. Required size particles are separated by a mesh separator at the top. Over- sized particles are fed back to the ball mill. Product is collected manually in bags (Fig.2). Exposure occurs at feeding and bagging operations. Normally 200 (74microns) mesh size product is manufactured.

**Exposure assessment**

Six small silica flour mills were selected for monitoring dust levels at Beawar (Rajasthan, India). House- keeping in general was very poor in all the mills. The quality of bags used for packing was also very poor. Two measures of bag quality are the porosity of the bag material and the tightness of the bag closure after filling. The exposure of workers to silica dust occurs at feeding and bagging operations. Workers are exposed continuously for 8 and sometimes more than eight hours. Total and respirable dust samples were collected using personal samplers (SKC) at a flow rate of 2.5 liters per minute (LPM) in six mills selected for the study. Cyclone used for collection of respirable dust samples has a median cut-off at 4 microns. Cellulose acetate membrane filters (37 mm diameter, 0.8 mm pore size) were used as sampling media. Dust control system was designed and installed at one of the mills. After installation of the dust control system, dust sampling was carried out again. The efficacy of the system was computed.

**Crystalline Silica Analysis**

Analysis of crystalline silica (Quartz) was carried out by Fourier Transform Infrared (FTIR) Spectroscopy (Bomem, Model MB 104), using Standard Reference Materials (SRM) supplied by National Institute of Standards & Technology (NIST,1999).

**(a) Sample Preparation**: In this method samples collected on membrane filters by personal samplers (37 mm diameter, 0.8 µm pore size) are placed in porcelain crucibles and ashed in muffle furnace for 2 hours at 600°C. After ashing, the ash is mixed with 200 mg of potassium bromide (IR grade).The mixture is dried overnight at 110°C and thoroughly mixed with pestle. The mixture is transferred carefully to a 13 mm evacuable pellet die using glassine paper and camel's hair brush. The pellet is then pressed by standard technique.

**(b) Calibration and measurement:** The standard pellets are prepared with known quantity of quartz (SRM 1878; NIST, USA). The spectra are taken in the range of 1000 - 600 $cm^{-1}$. Absorbance is measured at 800 $cm^{-1}$. The calibration curve is prepared using quant method software (Win-Bomem easy software). The method developed remains in the memory of the computer and can be applied directly on unknown samples. (NIOSH 1994; Cares et al, 1973; Bhagia, 2009).

**Design for the dust control system**

Dust control system involves hood, ducting, centrifugal fan and bag filters with reverse pulse jet system. One of the owners agreed to install the system on experimental basis. One hood each was installed at feeding and bagging points and connected to blower (with 5 hp motor) via bag filters. Dust control system was based on ACGIH ventilation guidelines (ACGIH 2004). It was decided to install canopy type of hood at feeding and bagging points. Duct velocity for silica dust was chosen as that for average industrial dust control i.e.3500-4000 feet per minute (FPM). For branches it was taken as 4000 FPM and for main duct it was taken as 3500 FPM. Ducts from feeding (4 inch diameter, CFM- 350) and from bagging (6 inch diameter, CFM- 785) were connected to bag filter and main duct from bag filter (8 inch diameter, total CFM-1135) was connected to Fan (Fig.3).

Based upon total CFM and air to cloth ratio of 5 CFM per square foot, 16 bags (9.84 feet X0.49 feet) were installed in an enclosed reverse pulse jet system.

**RESULTS AND DISCUSSION**

Analysis of crystalline silica (quartz) in the dust and Permissible Exposure Levels (PELs)

The infrared (IR) spectra of airborne dust and standard reference material (SRM) for quartz are shown in fig.4.

The spectrum clearly shows that the sample contains quartz having doublet at 800 $cm^{-1}$ and 780 $cm^{-1}$ and having a peak at 695 $cm^{-1}$ which are characteristics of quartz. The Permissible Level of Exposure (PEL) in case of dust containing quartz depends upon the percentage of quartz in the dust and is computed by following formulae as per Indian factory act (The Factories act 2008, Fulekar 1999):

PEL (Total dust) =30/% quartz +3

PEL (Resp. dust) =10/% quartz +2

Similar formulae are given by OSHA (Silica PELs and TLVs 1997; OH guidelines, 1978).According to above formulae, when the quartz is 100%, the PEL for total and respirable dust is 0.3 and 0.1 $mg.m^{-3}$ respectively. NIOSH has recommended exposure limit (REL) of 0.05$mg.m^{-3}$ for silica dust (OSHA 1978; NIOSH 2002). However, according to ACGIH (2008), the Threshold Limit Value (TLV) for respirable quartz is 0.025$mg.m^{-3}$.The analysis showed that average quartz content in airborne dust samples was 51.58 ± 4.57%.

**Exposure assessment**

Table-2 and 3 depict the quartz concentrations in feeding and bagging operations of different mills.

**Table-2: Quartz concentrations ($mg.m^{-3}$) in Feeding (Mean ± SE)***

| Mill | Feeding | |
|---|---|---|
| | Total Quartz | Resp.Quartz |
| A | 5.54±1.66 (5) | 1.26±0.16 (6) |
| **B** | 5.10±0.86 (4) | 1.23±0.16 (6) |
| **C** | 5.17±0.69 (6) | 1.19±0.41 (6) |
| **D** | 6.65±0.74 (5) | 1.13±0.09 (6) |
| **E** | 6.78±1.28 (4) | 1.28±0.36 (6) |
| **F** | 9.13±6.10 (7) | 0.62±0.21 (7) |

***Figures in parenthesis indicate number of samples**

**Table-3: Quartz concentrations ($mg.m^{-3}$) in Bagging (Mean ± SE)***

| **Mill** | **Bagging** | |
|---|---|---|
| | Total Quartz | Resp.Quartz |
| A | 6.66±0.86 (5) | 1.91±0.29 (6) |
| **B** | 6.08±0.30 (4) | 1.78±0.23 (6) |
| C | 9.11±0.47 (6) | 1.81±0.09 (6) |
| **D** | 8.16±0.87 (5) | 1.49±0.15 (6) |
| **E** | 13.08±2.45 (4) | 2.27±0.44 (6) |
| **F** | 18.47±7.40 (8) | 1.20±0.30 (8) |

***Figures in parenthesis indicate number of samples**

Quartz concentrations were obtained by multiplying dust levels with average quartz content in these mills i. e. 51.58%.A total of 138 samples (63 total and 75 respirable )samples were collected.

Permissible exposure level (PEL) for total and respirable quartz is 0.3$mg.m^{-3}$ and 0.1$mg.m^{-3}$ respectively. The total and respirable quartz concentrations in feeding and bagging operations (table-2 and 3) are much higher than the PEL. No sample was found to have quartz concentration less than PELs. Quartz concentrations in bagging operations (Table-3) were more than dust concentrations in feeding operations (Table-2). Mean total quartz concentrations in feeding were found to be in the range of 5.1 $mg.m^{-3}$ to 9.13 $mg.m^{-3}$ whereas in bagging the range was from 6.08 $mg.m^{-3}$ to 18.47$mg.m^{-3}$.Mean respirable quartz concentrations in feeding operation were found to be in the range of 0.62 $mg.m^{-3}$ to 1.28 $mg.m^{-3}$ whereas in bagging operation the range

was from 1.2 mg.m$^{-3}$ to 2.27 mg.m$^{-3}$.Mean total quartz concentrations were 18.33 -61.57 times higher than PEL for total quartz i.e.0.3 mg.m$^{-3}$. Respirable quartz concentrations were 6.20-22.70 times higher than PEL for respirable quartz i.e. 0.1 mg.m$^{-3}$.

**Dust reduction**

Tables-4 shows quartz concentrations in feeding and bagging operations with and without control in mill F.

**Table 4: Quartz concentrations (mg.m$^{-3}$) with and without dust control system (Mean ± SE)*.**

| **Mill** | **Feeding** | |
|---|---|---|
| F | Total Quartz | Resp.Quartz |
| Without control | 9.13±6.10 (7) | 0.62±0.21 (7) |
| **With control** | 1.00±.16 (8) | 0.14±0.00 (6) |
| **Reduction** | 89.04 **%** | 77.50 **%** |
| | Bagging | |
| Without control | 18.47±7.40 (8) | 1.20±0.30 (8) |
| **With control** | 0.57±0.18 (6) | 0.18±0.03 (7) |
| **Reduction** | 96.90 **%** | 84.91 **%** |

***Figures in the parenthesis indicate number of samples**

Total quartz concentration in feeding and bagging operations reduced by 89.04 **%** and 96.90 **%** respectively whereas respirable quartz concentration in feeding and bagging operations reduced by 77.50 **%** and 84.91 **%** respectively. Total and respirable quartz concentrations in feeding and bagging operations are still higher than PEL for total and respirable quartz i.e. 0.3 and 0.1 mg.m$^{-3}$ respectively. Hence further recommendations were given.

**Other recommendations**

1. It was recommended that transport of bags from bagging to store area should not be by dragging but trolleys carrying bags should be used to avoid fugitive emissions.
2. Good quality bags should be used. Opening of the bags should be of the size of the filling duct to avoid dust emission.
3. It is necessary to maintain good house- keeping and required to make proper checklist for work practices.

- Ensure that there is no dust accumulation on machinery, beams, corners and other surfaces.
- Dustless methods of cleaning such as vacuuming or wetting down should be used.
- Blowers with compressed air should not be used for cleaning machinery.
- Dry sweeping for cleaning should be avoided.
- Regular wet cleaning of floors should be encouraged.
- Facilities may be developed for vacuum cleaning of clothes of workers before removal.
- Storage of bags- Bag should be kept on wooden blocks at least six to eight inches above the ground so that flour can be easily washed with water.

4. Personal protective equipment (PPE) is not recommended as a primary means of control. However, it should be used in addition to the engineering control. It is also useful during installation, breakdown and maintenance of engineering control. Selection and type of PPE should be proper and effective.
5. There should be regular and periodic monitoring of work environment.
6. Workers health should be monitored periodically for early detection of the disease.

**Conclusions**

The aim of the study was to evaluate silica dust exposure in small silica flour mills of Rajasthan (India).Silica dust (quartz) concentrations in feeding and bagging operations were found to be much higher than the recommended permissible exposure levels (PELs). It was demonstrated practically that dust levels can be brought down by 77.50-96.90 % using suitable dust controls. Even after the installation of dust controls, dust concentrations were higher than the permissible exposure levels. It was concluded that in small silica flour mills engineering dust controls along with some other recommendations mentioned above may be used to prevent silica dust exposure.

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**Fig.1 Feeding of raw material**



**Fig.2 Bagging of finished product**



**Fig.3 Dust control system installed in mill F**

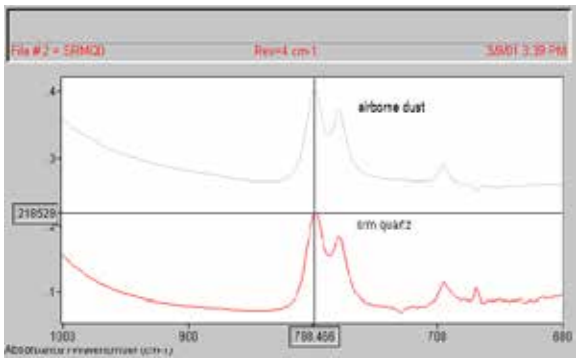



**Fig.4 IR Spectra of airborne dust and SRM**

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